BIOGRAPHY

The Aftermath of Charles Bell's Famous "Idea"

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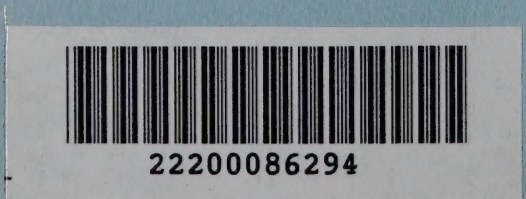
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THE AFTERMATH OF CHARLES BELL'S FAMOUS "IDEA"

J. M. D. OLMSTED

Anyone who comes upon a modern reference to the discovery of the functions of the spinal nerve roots [1] is almost certain to gain the impression that Charles Bell's pamphlet, "Idea of a New Anatomy of the Brain," privately printed in 1811, was written with the sole purpose of showing that the dorsal roots are sensory and the ventral roots motor. Strangely enough the pamphlet not only fails to make this distinction of function for the spinal nerve roots or even to imply it, but Bell had no such object in mind when he wrote. The subject of the spinal nerve roots was introduced only as a part of the proof of his main thesis, which was the general principle that different parts of the nervous system, particularly the cerebrum and cerebellum, have different functions. It is the story of the final disproof of the evidence which Bell brought forward to support his thesis which concerns us here.

In Bell's own words he was attempting in the "Idea" to combat the "prevailing doctrine of the anatomical schools . . . that the whole brain is a common sensorium . . . and that the mind by the same nerves which receive sensation, sends out the mandate of the will to the moving parts of the body" (p. 4); [2] and to prove "that the cerebrum and cerebellum are different in function as in form; that parts of the cerebrum have different function; and that the nerves which we trace in the body are not single nerves possessing various powers, but bundles of different nerves whose filaments are united for the convenience of distribution, but which are distinct in office, as they are in origin in the brain" (p. 5). . . . "That the

[1] See for example Max Neuburger's *British Medicine and the Vienna School*, Wm. Heinemann, London, 1943.

[2] Since only three copies of this pamphlet are known to be in existence, and since the accuracy of reprintings is often not to be relied upon, the passages quoted, although they were taken from the 13th volume of Karl Sudhoff's *Klassiker der Medizin*, have been verified by me by comparing them with the copy of the original edition in the British Museum, which bears on a flyleaf in ink the inscription, "With Mr. Bell's respectful compliments, 34 Soho Square."

nerves of sense, the nerves of motion, and the vital nerves are distinct through their whole course, though they seem sometimes united in one bundle; and that they depend for their attributes on the organs of the brain to which they are severally attached" (p. 6).

This last sentence is of the utmost importance for an understanding of Bell's "Idea." Here he gives his classification of nerves into three categories, sensory, motor and vital, and the object of his whole argument is to show which parts of the brain preside over the three functions, sensation, motion and vital properties. The first two functions are perfectly clear, but we must look to Bell himself for a definition of "vital nerves." He says (p. 15): "The secret operations of the vital organs suffer the control of the brain, though we are unconscious of the thousand delicate operations which are every instant going on in the body." It is evident that by this he meant what we might now term the autonomic nervous control of the viscera and other organs.

In Bell's opinion (p. 21) it was difficult if not impossible to experiment directly on the brain itself. Since, he said, "we can trace down the crura of the *cerebrum* into the anterior fasciculus of the spinal marrow, and the cruca of the *cerebellum* into the posterior fasciculus," he thought he could "touch" the cerebrum by stimulation of the anterior fasciculus of the cord, and the cerebellum by stimulation of the posterior fasciculus. He "found that injury done to the anterior portion of the spinal marrow, convulsed the animal more certainly than injury to the posterior portion" (p. 21). Then follow the now famous two short paragraphs which are always quoted by themselves divorced from their context, and entirely misinterpreted.

"Next considering that the spinal nerves have a double root, and being of the opinion that the properties of the nerves are derived from their connections with the parts of the brain, I thought I had an opportnuity of putting my opinion to the test of experiment, and of proving at the same time that nerves of different endowments were in the same cord, and held together by the same sheath.

"On laying bare the roots of the spinal nerves, I found that I could cut across the posterior fasciculus of nerves, which took its origin from the posterior portion of the spinal marrow without convulsing the muscles of the back; but that on touching the anterior

fasciculus with the point of the knife, the muscles of the back were immediately convulsed" (p. 22).

This experiment led him to conclude that "the cerebrum and cerebellum were parts distinct in function. . . . The spinal nerves being double, and having their roots in the spinal marrow of which a portion comes from the cerebrum and a portion from the cerebellum, they convey the attributes of both grand divisions of the brain to every part" (p. 23).

Now what did he think were the attributes of these two grand divisions of the brain which were conveyed along the different columns of the spinal cord and the spinal nerve roots? Into the cerebrum he said "all the nerves from the external organs of the senses enter; and from it all the nerves which are agents of the will pass out" (p. 27). The cerebrum was, therefore, the seat of both sensation and motion; the ventral columns of the spinal cord and the ventral roots of the spinal nerves were both sensory and motor; and the proof was that stimulation of the ventral roots caused observable convulsion of the limbs. Of the cerebellum he says (p. 36): "The secret operations of the bodily frame, and the connections which unite the parts of the body into a system, are through the cerebellum and the nerves proceeding from it." The key word is "secret" as is shown by its being used not once but three times (pp. 15, 25, 36) when "vital" nerves are mentioned. The proof of these "secret operations" lay in his finding that nothing visible happened when he stimulated the posterior roots.

The anatomy and physiology expressed in his "Idea" can be summed up thus: the cerebrum is the center for both sensation and motion, the pathway for both these functions is over the ventral columns of the spinal cord and the ventral roots of the spinal nerves; the cerebellum is the center for unconscious impressions from the body itself and involuntary movements, and their pathway is over the dorsal columns of the spinal cord and the dorsal roots of the spinal nerves.

That Bell ascribed both sensory and motor functions to the ventral roots is universally ignored, but this fact was very early pointed out by Johannes Müller. In a footnote of the English translation (1844) of his famous *Elements of Phsiology* are to be found these words:

" He (Bell) seems, it is true, to have supposed at first that the anterior roots contained nervous fibers for sensation as well as those for motion, while the posterior roots governed the ' operations of the viscera ' " (p. 304). Augustus Waller [3] in his acrimonious debate with Sir Arthur Keith made the same point over and over again but apparently without impressing his opponent. Bell's guess as to the specific functions of the dorsal and ventral roots was no nearer the truth than that of Alexander Walker, who seems to have been the first actually to propose that one set of spinal nerve roots serves for sensation, the other for motion. Walker's suggestion was published in the *Archives of Universal Science* in July, 1809, two years before the printing of Bell's pamphlet, but Walker ascribed sensation to the ventral roots and motion to the dorsal roots. It is interesting to note that Walker had the same conception of the relation of the dorsal and ventral columns of the cord to the dorsal and ventral nerve roots as Bell had, but to be consistent Walker had to say that sensory impressions were conveyed in an " ascending " direction via the ventral columns of the cord, while the dorsal or " descending " columns presided over motion.

Bell's thesis that different parts of the brain and individual nerve fibers have their own functions was an excellent one and is held to this day. He should be credited with having stated what is usually known as Johannes Müller's Law of Specific Nerve Energies. It is true that this concept had been foreshadowed by previous writers. For example, Bichat, who died in 1802, said in his lectures on General Anatomy, " Each nerve fiber, though belonging in its course to many nerve trunks, can very well fulfill its function in an isolated manner." But no one had attempted to locate the precise divisions of the central nervous system which serve as centers for motion, sensation, and those obscure nervous actions which maintain the life of the individual, in just the way Bell attempted to do, viz. by stimulation of remote parts supposedly connected with these centers. It will be seen that the basis for Bell's deductions was the possibility of his tracing true anatomical connections between the parts in question, and the soundness of his conclusions depended on the accuracy

[3] See *The Lancet*, vol. 80, pp. 470, 614, 835, 967, 1032, 1718. Also *Science Progress*, 6: 78, 1911.

with which he could establish such relations. It was unfortunate that the anatomical methods of that era could not give a true picture of the relationship of nerve pathways within the central nervous system.

When Magendie [4] in 1822 began his series of experiments which demonstrated that the dorsal roots were, as he expressed it, "mainly for sensation," and the ventral roots "mainly for motion," this was entirely new light on the question, and Bell at once revised his earlier conjecture. He now considered the dorsal roots to be purely sensory, and because of their supposed connections with the cerebellum via the dorsal columns of the spinal cord, the cerebellum must be the seat of sensation; the ventral roots to him now became purely motor, and since they were connected with the cerebrum via the ventral columns, the cerebrum became the center for motion. The vague "secret" nervous processes formerly attributed to the posterior columns and posterior roots were played down, but he added a respiratory function to the lateral columns of the spinal cord whose seat was in the medulla.

Since only 100 copies of the 1811 pamphlet had been printed and distribution had been made only to the author's private friends, this work was unknown to the scientific world. In 1824 Bell republished certain of his papers previously read before the Royal Society under the title, "An Exposition of the Natural System of the Nerves of the Human Body" prefacing them with a short introductory essay in which he outlined his revised concept as to the location of the different nerve centers. The book had immediate and wide recognition. It was immediately reprinted in the United States, and translated into French. It is to this book and particularly its subsequent editions which bore the title of "The Nervous System of the Human Body" (1833 and 1844) that most commentators have been forced to go for information regarding the famous "Idea." For example, Sherrington in his section on the spinal cord in Schäfer's well-known *Text-book of Physiology* says in a footnote (v. II, p. 279): "An Idea of a New Anatomy of the Brain, 1811, republished in 'An Exposition of the Natural System of the Nerves,' London, 1824." This is, of course, absolutely incorrect. It is true that the main

[4] *Journ. de Physiol. expér. et path.*, 2: 276, 1822.

theme of the " Idea " is outlined in the first few pages of this edition of the book, but because of the changes just noted, an utterly different impression from the original " Idea " is conveyed, and there is nothing to indicate that there was any change in attitude on Bell's part between 1811 and 1824. The later editions did contain excerpts from the " Idea," but only those passages were quoted which were consistent with an interpretation favoring the implication that the ventral roots were for motion and the dorsal roots for sensation.

One of the clearest statements of Bell's position at this juncture is to be found in certain passages of the 6th edition of his "Anatomy and Physiology of the Human Body " published in 1826, which were repeated verbatim in the 7th edition in 1829. He says (p. 24) : " I imagine that the same column or tract which gives origin to the fourth, seventh, glossopharyngeal, par vagum, and spinal accessory nerves, is continued downward along the lateral part of the spinal marrow, and that it affords roots to the spinal nerves, constituting them respiratory nerves, as well as nerves of motion and sensation." And on p. 29, " We have already explained that the cerebrum has connection with the anterior columns of the spinal marrow, and the cerebellum with the posterior columns. And no one has given reason to doubt the correctness of the statement I have made that the anterior column is for motion, and the posterior for sensibility. If we were to indulge in opinions which we could not bring to the test of experiment, we should say that the cerebrum had power over the motions of the body, and the cerebellum over its sensibility."

By 1844 Bell again changed his opinion, and returned to his former position that the cerebrum is the center of both sensation and motion. But he now claimed that he could " trace with equal precision " the dorsal columns of the cord into the pyramids at the base of the medulla, and eventually to the cerebrum (p. 22 of the 3rd edition of " The Nervous System "). Thus he still retained the fundamental aspects of his scheme as regards the relation of the three columns of the cord to the spinal nerve roots, and the extension of the functions of sensitivity, motility and respiration from centers in the nervous system out to the spinal nerve roots via these columns.

The division of each half of the white matter of the spinal cord into three columns—a dorsal column extending from the dorsal or

median fissure to the exit of the dorsal roots of the spinal nerves; a lateral column lying between the two sets of roots; and a ventral column lying between the exit of the ventral roots and the ventral median fissure—had come down from the time of Haller and Chaussier in the 18th century. After Magendie's experiments of 1822 had shown that operations on the spinal cord in living animals were a possibility, a great number of investigators tried their hands at cutting these columns separately at different levels. Rolando[5] came to the conclusion that section of the dorsal columns abolished movement but left sensibility. Ludwig Türk [6] thought he had proved that the lateral columns were the sole conductors of sensitivity. Others held still other views.[7] Bell's concepts prevailed, however, until 1855. In England it was his brothers-in-law, the Shaws, who championed his cause. In France he had a particularly vociferous advocate in F. A. Longet whose reputation was very high in the 1840's. In a separate pamphlet (1841)[8] as well as in his extensive *Treatise on Physiology* (1850) he aired the whole Bell-Magendie controversy in a light unfavorable to Magendie. In fact, his whole life seems to have been motivated by an insatiable desire to point out Magendie's mistakes. Longet added his own confirmation of what had now come to be called "Bell's doctrine" or even "Bell's Theorem." When he transsected the spinal cord he found that stimulation of the dorsal column generally produced no movement; stimulation of the lateral and ventral columns produced no pain; the cephalic portions of the dorsal columns were exquisitely sensitive; the caudal portion of the ventral columns readily caused motion; and stimulation of the gray matter produced neither movement nor pain.

By this time Bell's assumption of a respiratory function for the

[5] *Sperimenti sui fascicoli del midollo spinale,* Torino, 1828.

[6] *Sitzungberichte der Math. Naturwiss. Classe de K. Akad. d. Wissensch. zu Wien,* April, 1851.

[7] See page 54 of Brown-Séquard's *Soc. Biol.* memoir of 1855 for a complete list of discordant views regarding the pathway of transmission of sensory impulses to the "common sensorium," and of motor impulses to the muscles.

[8] *Recherches expérimentales et pathologiques sur les propriétés et les fonctions des faisceaux de la moelle épinière et des racines des nerfs rachidiens précédées d'un examen historique et critique des expériences faites sur ces organes depuis Sir Ch. Bell, et suivies d'autres recherches sur diverses parties du système nerveux,* Paris, 1841.

lateral columns had been dropped and Rolando's contention that each lateral half of the spinal cord should be considered to consist of two columns, "posterior" and "antero-lateral" had been widely adopted. Longet's confirmation of Bell's doctrine therefore related only to the functions of these two columns of the spinal cord and the corresponding spinal nerve roots. Longet said of Bell's doctrine that it was "one of the most beautiful, the most fecund and withal the *best established*, as we claim to have shown elsewhere, even to the most critical of minds" (p. 37 of his 1841 pamphlet).

In spite of the supposed unassailability of Bell's doctrine, especially after it had attained the refined form which Longet had given it, a dissenting voice was presently heard, but because of its source it caused no alarm.

On January 3, 1846, a 28-year old medical student defended before a committee of the Paris Faculty of Medicine for his M. D. degree a thesis entitled, "Researches and Experiments on the Physiology of the Nervous System." The author had been born in Mauritius while that island was in the possession of England, the son of a Philadelphia captain in the U. S. Merchant Marine and his wife, a lady of French descent. The thesis is signed simply C. E. Brown, but as the young man shortly added his mother's patronymic to his own, in order, he said, to distinguish him from the other Browns, he was none other than Charles Édouard Brown-Séquard. Half of his thesis was a criticism of Marshall Hall, and half a criticism of Longet. In the latter half we find the following remarkable statements: "I cut the posterior columns . . . sensitivity remained without great diminution in the parts lying behind the section." Again, "after having cut the antero-lateral and the posterior columns on one side of the cord in frogs, pigeons and rabbits, I have found the parts situated behind the section and on the same side to be apparently as sensitive as those on the sound side." There was not the slightest ripple of excitement over these unorthodox statements, for who pays attention to a student's thesis? The young man was undiscouraged and moreover, he was persistent. He reported his findings to the Paris Academy of Science in 1847, and when the Société de Biologie was founded in 1848 he not only made similar reports before its members, but he performed the operation of hemisecting the cord

FACULTÉ DE MÉDECINE DE PARIS.

THÈSE

POUR

LE DOCTORAT EN MÉDECINE,

Présentée et soutenue le 3 *janvier* 1846,

Par CHARLES-ÉDOUARD BROWN,

né au Port-Louis, île Maurice (Ile de France),

DOCTEUR EN MÉDECINE.

RECHERCHES ET EXPÉRIENCES

SUR LA

PHYSIOLOGIE DE LA MOELLE ÉPINIÈRE.

Le Candidat répondra aux questions qui lui seront faites sur les diverses parties de l'enseignement médical.

PARIS.

RIGNOUX, IMPRIMEUR DE LA FACULTÉ DE MÉDECINE,
rue Monsieur-le-Prince, 29 *bis*.

—

1846

1846. — *Brown*.

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of a guinea pig during the meeting of December 1, 1849. He cut the right half of the cord and showed that sensitivity persisted on the right side of the animal below the cut, and how was this possible if sensation was conveyed to the cerebrum via the dorsal columns of the cord? Nevertheless an autopsy performed by Claude Bernard verified the site and extent of the lesion. Even this brought no recognition that Brown-Séquard had made a fundamental discovery which was eventually to overthrow the major point of Bell's doctrine.

During the next three years Brown-Séquard reported experiment after experiment to the Paris Société de Biologie showing that transmission of sensation in the cord involves a crossing from one side to the other, and, what was still more incredible, far from the animal's losing sensitivity on the same side of the body below the site of hemisection, the parts bordering on the lesion were generally hypersensitive as compared with other parts. In 1852, fearing that his republican leanings were getting him into trouble with the French Government, he left hastily for the United States. Here he did more experiments and published two books on the subject. After a trip to his birthplace, Mauritius, to serve during the cholera epidemic, and a return to the United States where he accepted the professorship of physiology at the Medical College of Virginia at Richmond, we find him in 1855 back before the Société de Biologie in Paris still hammering away at his old thesis.[9]

At the session of the Society held on June 23, 1855, he sectioned the dorsal columns of the spinal cord in two rabbits, and again showed that sensitivity was not interrupted but that it was even increased in the region immediately below the lesion. Bell's doctrine died hard and even yet there were skeptics. It was said that the rabbit's cord was too small for one to be sure that the dorsal columns were completely severed and that larger animals should be used. A committee headed by Paul Broca, who, although seven years Brown-Séquard's junior, had made so meteoric a rise in the medical profession that he was already agregé in the Paris Faculty of Medicine and surgeon at the hospitals, was appointed to view Brown-Séquard's

[9] Recherches sur la voie de transmission des impressions sensitives dans la mœlle épinière (mémoire communiqué à la Société de Biologie en mai, juin et juillet 1855) *Mém. Soc. Biol.* 2, Ser. 2, 51, 1855.

attempt to hemisect the spinal cord of a horse and a sheep at the veterinary school at Alfort. (Apparently elephants were too difficult to come by for experimental purposes.) The other members of the committee were Claude Bernard, Vulpian and two professors from the veterinary school itself. The operations were successful as well as further demonstrations which Brown-Séquard performed on rabbits, guinea pigs and dogs. The committee was absolutely convinced of the correctness of Brown-Séquard's point of view as to the crossing of sensory fibers in the cord and of hypersensitivity below the section.

It was Broca's report [10] of this committee read before the Paris Société de Biologie July 21, 1855, which finally gave the necessary push that " overthrew the edifice so securely cemented together, whose foundations had been laid by Charles Bell, and whose capstone had been sealed in place by Longet " (Broca's Report, p. 27). The symptoms appearing after hemisection of the spinal cord, which are, in broad outline, disappearance of sensation on the opposite side of the body below the lesion and motor paralysis on the same side, are now called the " Brown-Séquard Syndrome," and are well known to all physiologists and physicians. Only after the introduction of Waller's method of tracing nervous tracts by degeneration and the Marchi method of staining, did our knowledge of pathways in the central nervous system become precise. The anatomical methods of Bell's day were too crude to give this information, but so great was his authority that for more than a quarter of a century the incorrect evidence he had adduced to support his famous " Idea " was the accepted neurological doctrine whose validity it was heresy to question.

[10] Rapport sur les expériences de M. Brown-Séquard relatives aux propriétés et aux fonctions de la mœlle épinière, lu à la Société de Biologie, le 21 juillet 1855. Paul Broca, *Mém. Soc. Biol.*, *2*, Ser. 2, *23*, 1855.